U.S. EPA OSWER
Selected Sites Using or Testing Nanoparticles for Remediation

Site Information							Media		Contaminants			Technology Information		Vendor Information	
Site Name	**Site location (city, state)**	**EPA Region**	**Site type**	**Cleanup program**	**Scale**	**Geology**	**Media treated**	**Volume of media treated**	**Contaminants treated**	**Initial contaminant concentrations**	**Final contaminant concentrations**	**Type of nanoparticle**	**Technology design**		**Cleanup/ remedial objectives and goals**
Naval Air Engineering Station	Lakehurst, NJ	2	Aircraft launching activity testing	CERCLA	Full	Coastal Plain Aquifer consisting of mostly sand and gravel	Soil and Groundwater	Not available	PCE, TCE, TCA, c-DCE, vinyl chloride	Maximum VOC concentration: 900 µg/L	Average total VOC concentration decreased by 74%	BNP	300 lb of BNP was made into 2-g/L slurry; injected by direct push at 10 locations within the northern plume and five locations within the southern plume; 2,300 total lbs injected in 2005 and 500 total lbs injected in 2006	PARS Environmental, Inc., Environmental Chemical Corporation, Inc.	Achieve decreasing trends in contaminant concentrations
Naval Air Station	Jacksonville, FL	4	Former UST Site	CERCLA	Full	Silty to fine sand from 0 to 24 feet bgs; dense clay from 24 to 54 feet bgs	Groundwater	Not available	TCE, TCA, DCE, vinyl chloride	Max TCE: 26,000 ug/L Max TCA: 11,000 ug/L Max DCE: 44,000 ug/L	Rapid reductions by 65% to 99%	BNP	300 lb of BNP was made into 4.5 to 10 g/L slurry; combination of direct push and closed-loop recirculation	PARS Environmental, Inc.	Reduce total site contaminant mass by 40-50%
Patrick AFB, OT-30	Patrick AFB, FL	4	Industrial Area	RCRA	Full	Groundwater encountered 4 to 5 feet bgs. Upper surficial aquifer mostly fine to medium grained sands with occasional silt/clay. Silty region around 35 to 42 ft bgs holding DNAPL migration.	Soil and Groundwater	600,000 ft^3, 22,222 cy	TCE and corresponding daughters	Initial TCE as high as 150,000 ug/L	highest remaining TCE post treatment - 3,580 ug/L	Emulsified ZVI (EZVI)	High pressure pneumatic injection	Jacobs Engineering Group (Prime)	Reduction of significant source mass (interim)/Florida groundwater target levels (ultimate)
Launch Complex 15	Cape Canaveral, Air Force Station, FL	4	Abandoned Space Launch Complex	RCRA	Full	Groundwater encountered 4 to 5 feet bgs. Upper surficial aquifer mostly fine to medium grained sands with occasional silt/clay. Silty region around 45 ft bgs holding DNAPL migration.	Soil and Groundwater	7,500 ft^3, 280cy	TCE and corresponding daughters	Initial TCE as high as 439,000 ug/L	In the EZVI zone, the area with >400,000 ug/L has dropped to 28 ug/L	Emulsified ZVI (EZVI)	Drop Tip injection	Jacobs Engineering Group (Prime)	Reduction of significant source mass (interim)/Florida groundwater target levels (ultimate)
Space Launch Complex 34	Cape Canaveral, FL	4	Former Rocket Launch Site	Not available	Pilot	Upper portion of surficial aquifer known as Upper Sand Unit, underlain by Middle Fine-Grained Unit which makes up a hydraulic barrier to Lower Sand Unit	Soil and Groundwater	Not available	TCE	Not available	Average TCE reduction of 58%, where eZVI was present >80% reduction. Chloride increase is attributed to reduction of TCE, pH level changes were short lived - returned to low levels of pre-demonstration data, ethane and ethene concentrations increased.	Emulsified ZVI (EZVI)	High pressure injection, pneumatic injection and pressure pulse enhanced injection techniques used. 61 gallons of eZVI injected into upper sand unit; 8 injections made at depths ranging from 16 to 24 ft bgs	Geosyntec Consultants	Estimate change in TCE and DNAPL mass in test plot, evaluate change in aquifer quality due to eZVI treatment, evaluate fate of TCE due to injection, verify eZVI operating requirements and costs

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Site Name	**Site location (city, state)**	**Were cleanup goals and objectives met? (Yes/No)**	**Performance data available (Yes/No)**	**Maintenance (O&M) activities/ monitoring system**	**Start date/date installed**	**Anticipated end date of current phase**	**Length of operation**	**Comments**				
Naval Air Engineering Station	Lakehurst, NJ	Yes	Yes	Groundwater samples were taken from 13 monitoring wells; Six post injection sampling events during week 1, 2,4,8,12 and 6 months after BNP injection	Phase I - Nov-05 Phase II - Jan-06	Not available	Not available	ORP data: Pre-Injection:170 to 311 mV Post-Injection: -100 to -400 mV TCE levels decreased in half the wells and increased in the other half. ORP levels did not decline and increased in several wells. Groundwater pH remained below 6; no increase in DCE levels. Site conditions remain unfavorable for biostimulation and abiotic reduction	Not available	Not available	Paul Ingrisano, RPM EPA, Region 2 212-637-4337 ingrisano.paul@epa.gov	*Remedial Action Report for Nanoscale Particle Treatment of Groundwater at Areas I and J Naval Air Engineering Station Lakehurst, NJ; June, 2006. NAVFAC Cost and Performance Report Nanoscale Zero-Valent Iron Technologies For Source Remediation* http://www.clu-in.org/download/remed/cr-05-007-env.pdf Tech News and Trends - September 2005 http://cluin.org/products/newsltrs/tnandt/view.cfm?issue=0905.cfm
Naval Air Station	Jacksonville, FL	Yes	Yes	Groundwater samples were collected 6 weeks after injection from select wells	Jan-04	Through 2007	1st monitoring event was 5 weeks after initial injection, monitoring continued beyond the original 9 months	ORP data: Levels dropped to below -200 mV Daughter products of parent VOCs were detected, some levels of daughter product concentrations increased sharply and then decreased; high levels of anaerobic reductive products indicated reduction by microbial action or hydrogenolysis	Not available	Establish institutional controls to prevent human exposure to contaminated groundwater until natural attenuation takes place	Keith Henn Tetra Tech NUS 412-921-8146 Kieth.Henn@ttnus.com	*Utilization of nanoscale zero-valent iron for source remediation - A case study. Keith W. Henn and Dan W. Widell. Remediation, Spring 2006. NAVFAC Cost and Performance Report Nanoscale Zero-Valent Iron Technologies For Source Remediation http://www.clu-in.org/download/remed/cr-05-007-env.pdf; Email from Keith Henn to Marti Otto dated 11/24/2004; Henn and Waddell. 2005. U.S. EPA Nanotechnology Workshop*
Patrick AFB, OT-30	Patrick AFB, FL	TBD	Yes	Semi-annual monitoring	Nov-05	1-Nov-10	On-going, minimum 5 years	ORP and DO decreasing	Unit cost, $180/cy Monitoring: ~$70,000/yr Capital costs: $1M eZVI, $1M Pneumatic injection contractor Total remedial cost: $4M	Site currently in long term performance monitoring, evaluating impacts to plume post source reduction	Mark Kershner Mark.Kershner@patrick.af.mil	OT-30 Corrective Measure Implementation (CMI) Report
Launch Complex 15	Cape Canaveral, Air Force Station, FL	TBD	Yes	Semi-annual monitoring	Feb-06	1-Feb-11	On-going, minimum 5 years	ORP and DO decreasing	Monitoring: $40K/yr	Site currently in long term performance monitoring, evaluating impacts to plume post source reduction	Mark Kershner Mark.Kershner@patrick.af.mil	Space Launch Complex 15 Groundwater Remediation Report
Space Launch Complex 34	Cape Canaveral, FL	Yes	Yes	Soil sampling was conducted (from groundwater table down to lower sand unit) prior to injection, directly after injection and 6 weeks after injection; groundwater samples were taken by vendor from multilevel samplers within plot area	Jun-02	Not available	8 months	ORP and DO decreased slightly after the eZVI injection; groundwater pH remained stable	Site characterization cost: $352,000 Performance assessment cost: $275,000 Vendor total: $327,000	Not available	Suzanne O'Hara Geosyntec Consultants 519-822-2230 ext.234 sohara@geosyntec.com Jacqueline Quinn NASA 321-867-8410	*Demonstration of in situ Dehalogenation of DNAPL Through Injection of Emulsified Zero-Valent Iron at Launch Complex 34 in Cape Canaveral Air Force Station, FL* Battelle, September 10, 2004 *Nanotechnology Applications for Remediation: Cost-Effective and Rapid Technologies Removal of Contaminants From Soil, Groundwater and Aqueous Environments* Greg Wilson http://es.epa.gov/ncer/publications/meetings/8-18-04/ppt/greg_wilson.ppt#256,1,Nanotechnology%20Applications%20for%20Remediation:%20Cost-Effective%20and%20Rapid%20Technologies;%20Removal%20of%20Contaminants%20From%20Soil,%20Ground%20Water;%20and%20Aqueous%20Environments

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Parris Island	Port Royal, SC	4	Marine Corps Recruit Depot Former Dry Cleaner	CERCLA/ Private	Pilot	Small, relatively flat, sandy island with minimal topographic relief. Highest elevation on site is approximately 9 feet above mean sea level (msl). Soil present is from Seabrook, Capers, and Bohicket series. 15 different soil types.	Soil and Groundwater	Not available	PCE, TCE, c-DCE, vinyl chloride	Groundwater: Max PCE: 32,000 ug/L Max TCE: 10,000 ug/L Max c-DCE: 3,400 ug/L Max vinyl chloride: 710 ug/L	Not available	EZVI	October 2006: Injected 17 barrels EZVI (55 gallons/barrel) at two injection plots. Direct push and pneumatic injection. ~600 gallons of EZVI were injected into the pneumatic test plot using pneumatic injection technique from 4 to 19 ft bgs; injected ~150 gal of EZVI into a direct injection plot using direct push rig from approximately 6 to 12 ft bgs	Geosyntec Consultants	- Evaluate the long-term performance of nanoscale EZVI injected into the saturated zone to enhance *in situ* dehalogenation of DNAPLs containing TCE. - Estimate change in PCE and DNAPL mass in test plot, evaluate change in aquifer quality due to EZVI treatment, evaluate injection technologies, verify eZVI operating requirements and costs
Vandenberg Air Force Base	Santa Maria, CA	9	Missile Launch Pad	CERCLA	Pilot	Interbedded sands, silts, and clays referred to as the Orcutt Formation; bedrock encountered below the alluvium at depths of approximately 40 to 50 feet bgs	Groundwater	Not available	TCE, DCE	TCE: 2.5 mg/L	Not available	BNP	Not available	Not available	Not available
Phoenix Goodyear Airport - North (Unidynamics) Phase I	Goodyear, AZ	9	Former Missile development R&D facility	CERCLA	Pilot	Alluvial deposits of Western Salt River Valley. Deposits consist of upper alluvial unit, middle fine-grained unit, and lower conglomerate unit Groundwater at 85ft bgs. Target injection interval ad 110 to 120 ft bgs.	Groundwater	Not available	TCE, PCE, Perchlorate	Up to 39,000 ug/L	Not available	nZVI	Injection of 30g/L nZVI slurry in water through injection well with 10-foot long 6-inch diameter stainless steel wire wrapped 0.03-slot screen. Injection below packer placed in well casing.	Polyflon Company PolyMetallix™	Achieve target compound concentration decreases in source area; Collect information for design of full scale.
Phoenix Goodyear Airport - North (Unidynamics) Phase II	Goodyear, AZ	9	Former Missile development R&D facility	CERCLA	Pilot	Alluvial deposits of Western Salt River Valley. Deposits consist of upper alluvial unit, middle fine-grained unit, and lower conglomerate unit Groundwater at 85 ft bgs. Target injection interval ad 110 to 120 ft bgs.	Groundwater	Not available	TCE, PCE, Perchlorate	3,500 to 11,000 ug/L	Not available	nZVI	Gravity feed nZVI 10,400 liters (2,750 gallons) of a 2.1 g/L nZVI suspension totaling 22 kg (49 lbs) of nZVI injected through injection well with 10 foot long 6 inch diameter stainless steel wire wrapped 0.03 slot screen. Used deoxygenated site water, sodium hexametaphosphate dispersing agent, and onsite colloid mill to address potential agglomeration issues.	Polyflon Company PolyMetallix™	Achieve target compound concentration decreases in source area; Collect information for design of full scale.

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Site Name	Site location (city, state)	Were cleanup goals and objectives met? (Yes/No)	Performance data available (Yes/No)	Maintenance (O&M) activities/ monitoring system	Start date/date installed	Anticipated end date of current phase	Length of operation	Comments				
Parris Island	Port Royal, SC	Yes	Yes	June 2006: installed six fully screened and seven multi(7) level monitoring wells. Groundwater baseline sampling in June and August 2006. Post-injection groundwater monitoring in Nov/Dec 2006, Jan 2007, March 2007, July 2007, and Jan 2008	Jun-06 Oct-06	Sept-07 Oct-08	Ongoing	Downgradient wells showed a decrease in PCE/TCE with increase in degradation products including significant increases in ethene; Upgradient wells and PMW-5 show continued presence of DNAPL although significant production of ethene in PMW-5 indicates that degradation is ongoing in the area; Significant increases in VFAs (primarily acetic and propionic acids) and TOC; Small decrease in pH, and increases in iron (dissolved and total)	Not available	Conduct sampling and analysis in July and October, 2008.	Suzanne O'Hara Geosyntec Consultants 519-822-2230 ext.234 sohara@geosyntec.com Thomas Krug Geosyntec Consultants Mark Watling Geosyntec Consultants Nancy Ruiz U.S. Navy 805-982-1155 nancy.ruiz@navy.mil Jackie Quinn, NASA Chunming Su, EPA 580-436-8638 su.chunming@epa.gov Bob Puls, EPA	Email from Suzanne O'Hara, 19 February 2008 Email from Chunming Su, 6 February 2008 Phone conversation with Thomas Krug on 6/21/06./ Record of Decision for Site 12/SWMU10 - Jericho Island Disposal Area
Vandenberg Air Force Base	Santa Maria, CA	N/A	No	Not available	Not available	N/A	N/A	N/A	Not available	Not available	Andrea Leeson Dept. of Defense 703-696-2118 Andrea.Leeson@osd.mil	Tech News and Trends - March 2004 http://www.clu-in.org/products/newsltrs/tnandt/view.cfm?issue=0304.cfm
Phoenix Goodyear Airport - North (Unidynamics) Phase I	Goodyear, AZ	No	Yes	Sampling at variable time intervals	Jan-08	Mar-06	2 days, post injection monitoring for two months	Limited ORP decrease at injection well, wells & formation clogged by injection.	Not available	1st test unsuccessful due to problem with delivery of nanoparticles; Conduct further injections using new wells and different solutions, including sodium hydroxide and hexametaphosphate. Injections proposed for Spring 2008.	Glenn Bruck, EPA 415-972-3060 bruck.glenn@epa.gov Robert J. Ellis, L.G. ARCADIS-US 248-994-2252 rob.ellis@arcadis-us.com	Preliminary & final report for Phase I testing. Ellis, Robert J., Harry S. Brenton, David S. Liles; Michael A. Hansen. 2007. Nanoscale Zero Valent Iron Bench Scale Kinetic and Phase II Injection Testing, Phoenix-Goodyear Airport North Superfund Site, Goodyear, Arizona. U.S. EPA Desert Remedial Action Technologies Conference Proceedings. http://www.epa.gov/osp/presentations/drat/D-RAT_Workshop_Proceedings_(Oct_2-4,_07).pdf http://epameetings.com/meeting_details.cfm?meet_id=20
Phoenix Goodyear Airport - North (Unidynamics) Phase II	Goodyear, AZ	Not available	Post- injection monitoring ongoing	Ongoing periodic monitoring at three wells (5 feet, 10 feet, and 14 feet from injection well) for three to six months.	Jun-08	Dec-08	3 days, post injection monitoring for three to six months	Initial 400 mV ORP decrease at 5-foot downgradient well. Partial Loss of formation permeability.	Not available	TBD based on analysis of post-injection monitoring and completion of remedial alternatives evaluation	Robert J. Ellis, L.G. ARCADIS-US 248-994-2252 rob.ellis@arcadis-us.com	Abstract: "Nanoscale Zero Valent Iron Phase II Injection Field Pilot Study, Phoenix-Goodyear Airport North Superfund Site, Goodyear, Arizona" Authors: R.J. Ellis, H.S. Brenton, D.S. Liles, C. McLaughlin, N. Wood in U.S. EPA International Nanotechnology Conference October 5-7, 2008 Proceedings.

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Industrial Site	Edison, NJ	2	Former Adhesives Manufacturer	Private	Pilot	Fractured bedrock, specifically Brunswick Shale. 4 to 6 feet of soil comprised of silt and clay over bedrock	Fractured Bedrock	Not available	TCA, TCE, DCA, DCE, chloroethane, vinyl chloride	Maximum TCA concentration: 37,000 mg/L; 10,000 µg/L TCA at injection well 1; presence of DNAPL possible	Decreased to a level below minimum detection limit; ethane concentration in well 1 steadily increased	nZVI (OnMaterial's Z-loy)	300 lbs nZVI and 1,500 gallons emulsified vegetable oil comprised mixture; Injection took place at two places; injected at pressures between 25 and 50 lbs psi.	Delta Environmental Consultants, Inc.	Not available
Manufacturing Site	Passaic, NJ	2	Former Manufacturer	Not available	Pilot	Soils from 0 to 20 feet bgs composed of high permeability sands; silt unit exists from 20 to 26 feet bgs	Groundwater	Not available	TCE	450 to1,400 µg/L	90 to100% reduction in TCE concentrations	nZVI	108 lbs of nZVI slurry and 1,200 lbs of emulsified oil was injected into 3 points within the silt unit; pneumatic fracturing injection was used at two injection points, hydraulic injection was used at the third point	Not available	Not available
Pharmaceutical Facility	Research Triangle Park, NC	4	Former Waste Disposal Area	RCRA	Pilot	Durham Triassic Basin Sandstone interbedded with siltstone grading downward into mudstones	Groundwater in fractured bedrock	Not available	PCE, TCE, DCE, VC	14,000 µg/L	Over a 90% reduction of pre-injection baseline concentration at injection well and observation well. DCE concentrations reduced to near or below groundwater quality standards, with no accompanying increases in vinyl chloride concentrations.	BNP = bi-metallic nano-scale iron produced in laboratory by Lehigh University	BNP slurry concentration of 1.9 g/L; total slurry volume 6,056 L; average injection rate 0.6 gallons per minute	Pilot test designed and implemented by Golder Associates Inc. (Florin Gheorghiu, Jarrett Elsea)	Source mass reduction
Nease Chemical	Salem, OH	5	Former Pesticides Manufacturer	CERCLA	Pilot	Glacial till overburden lying above fractured sedimentary bedrock	Groundwater in fractured bedrock	Not available	PCE, TCE, DCE, VC	100,000 ug/L	40-70% reductions in PCE 20-70% reductions in TCE increases in cis-DCE net decrease in VOCs low	Golder Associates nZVI: nano-scale zero-valent iron (nZVI) produced by Golder Associates Inc. under license from Lehigh University	nZVI slurry concentration of 10 to 20 g/L; Total nZVI injected 70 Kg	Pilot test designed and implemented by Golder Associates Inc. (Stephen Finn, Allen Kane, Florin Gheorghiu)	Pilot goals: achieve reduction in target compounds, collect information for design of full scale
BP -- Prudhoe Bay Unit	North Slope, Alaska	10	Oil Field	RCRA	Pilot	Organics over alluvial gravels	Soil	Not available	TCA, Diesel fuel	Maximum TCA: 58,444 ug/kg	Shallow Test: TCA reduction of ~60% Deep Test: TCA reduction of up 90%	BNP	Shallow Test: (soil 0 to 4 ft. bgs), physical mixing with lake water Deep Test: (soil 0 to 7.5 ft. bgs). Pressurized injection via 20 injection pts/ at 6.5 ft. bgs	Pars Environmental, Inc. Lehigh University	Not available

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Industrial Site	Edison, NJ	Not available	No	Injection well and two downgradient monitoring wells were monitored for 13 months	Not available	Not available	13 months	N/A	Not available	Not available	Jon Josephs, STL EPA, Region 2 212-637-4317 josephs.jon@epa.gov	Chu, Peylina, John Mateo, Sam Fogel, John Freim, Clint Bickmore, William Newman, David Crisman. 2005. *Rapid In-situ Dechlorination of Solvents by Abiotic and Biotic Mechanisms.*
Manufacturing Site	Passaic, NJ	Not available	Yes	Monitoring weekly during the first month, monthly monitoring thereafter	Sep-05	Not available	6 months	ORP data: Pre-Injection = 375 to 550 mV with a pH between 3 - 4.5 After 1 week levels dropped to less than -500 and -300 mV Anaerobic bacteria developed, anaerobic oxidation coupled to iron reduction	Not available	Not available	David Liles ARCADIS 919-544-4535 david.liles@arcadis-us.com	Zhang, W.-X., N. Durant and D. Elliott. *"In situ remediation using nanoscale zero-valent iron: fundamentals and field applications."* Battelle Conference on Remediation of Chlorinated and Recalcitrant Compounds, Monterey California. May 22-25, 2006
Pharmaceutical Facility	Research Triangle Park, NC	Pilot test objectives met	Yes	Three monitoring wells at distances 6.6, 13, and 19 meters downgradient of injection well	Sep-02	Completed December 2002	3 months	ORP data: Initial values about +100 mV; after 3 days -400 mV; maintained at -500 to -400 mV for more than 3 months Treatment radius of influence approximately 63 feet. Limited influence of biological activity	Not available	Full-scale system design to be completed in 2008	Florin Gheorghiu, Golder Associates 856-793-2005 fgheorghiu@golder.com Wei-xian Zhang Lehigh University 610-758-5318 wez3@lehigh.edu	*Nanoscale iron particles for environmental remediation: An overview.* Wei-xian Zhang. Journal of Nanoparticle Research 5: 323-332. 2003. *Applications of Iron Nanoparticles for Groundwater Remediation* Wei-xian Zhang and Daniel W. Elliot REMEDIATION Spring 2006 *Nanotechnology Takes Root*. Robert Glazier, Ramesh Venkatakrishnan, Florin Gheorghiu, Lindsey Walata, Robert Nash, and Wei-xian Zhang, Civil Engineering Magazine May 2003. *In-Situ Treatments using Nano-Scale Zero-Valent Iron Implemented in North America and Europe.* Florin Gheorghiu, Mace Christian, Ramesh Venkatakrishnan, Wei-xian Zhang. U.S. EPA Workshop on Nanotechnology for Site Remediation U.S. Department of Commerce, Washington DC. October 20 – 21, 2005
Nease Chemical	Salem, OH	Yes	No	Not available	2007	Not available	Not available	N/A	Pilot cost: $177,000 Estimated full scale cost - $19 million	Phase I -Bench,Aug-2006 Phase II - Field, Nov-Dec-2006	Mary Logan EPA 312-886-4699 logan.mary@epa.gov	OEPA Fact Sheet - June 2005
BP -- Prudhoe Bay Unit	North Slope, Alaska	Not available	Yes	Shallow test: n/a Deep Test: 4 monitoring wells installed, monitored every 24 hours for 6 days	Shallow Test: Not available Deep Test: 29-Aug-08	Shallow Test: Not available Deep Test: 30-Aug-08	Shallow test: n/a Deep Test: 40.5 hours	N/A	Not available	Not available	Roberta Hedeen EPA, Region 10 206-553-0201 hedeen.roberta@epa.gov	Email from Roberta Hedeen to Marti Otto *Bimetallic Nanoscale Particle Technology Test, Tuboscope Site Pilot Test Results, Greater Prudhoe Bay, North Slope Alaska*, Draft v. 3, May 3, 1007

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Industrial Plant	Rochester, NY	2	Former Manufacturing	NYSDEC RCRA	Pilot	Glacial till overburden lying above fractured sedimentary bedrock.	Groundwater in bedrock	Not available	Methylene chloride, 1,2-dichloropropane, 1,2-dichlorethane	500,000 ug/L	50,000 ug/L	Golder Associates nZVI: produced by Golder Associates Inc. under license from Lehigh University	nZVI slurry concentration of 10 to 20 g/L; Total nZVI injected 100 Kg; Gravity feed injection.	Pilot test designed and implemented by Golder Associates Inc. (Allen Kane, Florin Gheorghiu)	Pilot goals: achieve reduction in target compounds, collect information for design of full scale
Picatinny Arsenal Superfund Site	Rockaway Township, NJ	2	Munitions Arsenal	CERCLA	Pilot	Organics-rich soil	Groundwater	Not available	Carbon tetrachloride, TCE	250 ppb of CCl_4 87 ppb of TCE	Carbon tetrachloride was 180 ppb four weeks after injection, but rebounded to 230 ppb four months after injection; TCE was 54 ppb four months after injection	nZVI (Ferragel Particles)	Injection via two 4-inch temporary injection wells. Approx. 120 lbs of nZVI were injected	Shaw Environmental, Inc. and PARS Environmental, Inc.	2 ppb carbon tetrachloride, 1 ppb TCE
Valcariter Garrison	Quebec, Canada	NA	National Defense Site	NA	Pilot	Deltaic and Proglacial Sands	Sands and clayey silts	~4,500 m^3	TCE, DCE, VC	TCE = ~300 ppb, DCE = ~50 ppb	TCE = <5 ppb, DCE = <50 ppb	Golder Associates nZVI with Pd catalyst, and soy powder dispersant; nZVI: produced by Golder Associates Inc. under license from Lehigh University	4,550 kg nZVI/BNP injected with Soy Protein surface modification. Injection using multiple screen wells and packers for unit specific placement. Follow-up with groundwater recirculation and enhanced bioremediation.	Pilot test designed and implemented by Golder Associates Ltd.. (Sylvain Hains)	Pilot goals: achieve reduction in TCE below 5 ppb , collect information for design of full scale
* Residential Site	Ringwood, NJ	2	Residence	Private	Full	Contamination extended to 19 ft. below surface as well as under deck and residence. Groundwater was approximately 6 feet below surface.	Groundwater	275 cubic yards	Home heating oil: Tetrachloroethene Bis(2-Ethylhexyl)phthalate Benzo[a]Anthracene	Tetrachloroethene - 1.1 ug/L Bis(2-Ethylhexyl)phthalate - 9.8 ug/L Benzo[a]Anthracene - 0.14 ug/L	Tetrachloroethene - 1.1 ug/L Bis(2-Ethylhexyl)phthalate - 9.8 ug/L Benzo[a]Anthracene - 0.14 ug/L	Nanoscale calcium ions with noble metal catalyst (Nano-Ox™)	825 lbs of Nano-Ox was mixed with water to form a slurry and direct-push injected into the impacted area	Continental Remediation LLC	Reduce contaminant concentrations to at or below NJDEP standards
* Klockner Road Site	Hamilton Township, NJ	2	Fill Area	Private	Full	Middle Potomac Raritan Magothy (MPRM) Aquifer; consisting of water-bearing soils that extend to the underlying schist/gneiss bedrock from 130 to 160 feet bgs	Groundwater	Not available	TCE, DCE, TCA, DCA	Total VOC: 400-1600 ppb	Reduction in dissolved chlorinated contaminants at concentrations by up to 90%	Nanoiron slurry (NanoFe Plus™)	NanoFe Plus™ injected in water slurry at concentration up to 30 g/L; Phase I injection totaled 3,000 lbs injected over a period of 20 days at the Northern end of the site, Phase II totaled 1,500 lbs that was injected throughout the northern half of treatment area over 10 days	PARS Environmental, Inc.	Reduce dissolved chlorinated contaminant "hotspots" in the Perched Water zone and allow remaining contaminant concentrations to be reduced over time by Monitored Natural Attenuation

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Performance Information									Cost Information	Future Work/Current Plans	Contact Information	Information Sources
Site Name	**Site location (city, state)**	**Were cleanup goals and objectives met? (Yes/No)**	**Performance data available (Yes/No)**	**Maintenance (O&M) activities/ monitoring system**	**Start date/date installed**	**Anticipated end date of current phase**	**Length of operation**	**Comments**				
Industrial Plant	Rochester, NY	Yes	No	Not available	2004	Not available	Not available	N/A	Not available	Not available	Allen Kane, Golder Associates 610-941-8173 akane@golder.com	Email communication from Golder Associates and ***"Nanotechnology and Groundwater Remediation, A Step Forward in Technology Understanding,"*** Christian Macé, Florin Gheorghiu, Steve Desrocher, Allen Kane, Michael Pupeza, Miroslav Cernik, Petr Kvapil, Ramesh Venkatakrishnan, and Wei-Xian Zhang, 2006, Remediation Journal, Wiley Periodicals, Inc., Spring 2006.
Picatinny Arsenal Superfund Site	Rockaway Township, NJ	No	Yes	Four monitoring wells were installed and four rounds of sampling conducted	Aug-04	Final report dated Aug-2005	1 year	N/A	Not available	Decided to utilize different technology to remediate site.	Bill Roach, RPM EPA, Region 2 212-637-4335 roach.bill@epa.gov Jon Josephs, STL EPA, Region 2 212-637-4317 josephs.jon@epa.gov	*Picatinny Task Order 17, Site 2, Nanoscale ZVI Pilot Study Report,* August 2005.
Valcariter Garrison	Quebec, Canada	Yes	Yes	Not available	July 2006	May 2007	12 months	ORP levels reached ~-500 mV after injection, remained lower than background for >12 months	Not available	Potential full-scale implementation in 2009	Sylvain Hains Golder Associates 418-781-0285 SHains@golder.com	*Implementation of nZVI Reactive Zone for the Treatment of TCE in a Deep Aquifer.* Sylvain Hains. Power Point Presentation and Platform Paper. Battelle 2008
* Residential Site	Ringwood, NJ	Yes	Yes	Injections were performed on 6/27/07 and the first groundwater samples taken on 7/31/07. Only one compound was marginally over the NJDEP standards. All were below by 9/27/07.	27-Jun-07	27-Sep-07	2 DAYS	N/A	Not available	Job completed	Joe Malinchak, Ph.D. Environmental Restoration Services, LLC. 52 Lisa Drive Chatham, NJ 07928 Ph: 973 632-0045 Fax: 973 635-8323 Website: www.ersllccorp.com E-mail: drjoseph1@comcast.net	E-mail from Joe Malinchak, 4 June 2008
* Klockner Road Site	Hamilton Township, NJ	Yes	Yes	ORP, pH and groundwater elevations were monitored during each phase of injection; 1st post injection monitoring began a week after completion of first injection, 2nd monitoring was performed 2 weeks after phase II injection, 3rd monitoring event was performed a month after 2nd monitoring	Not available	Not available	Phase I - 20 days Phase II - 10 days	ORP data: Pre-injection= 200 to 450 mV Post-injection= -350 to 450 mV Nanoiron slurry migrated through Perched Water zone	Not available	Continue monitoring activities, including collection of groundwater quality data to demonstrate trends in remaining groundwater contamination	H.S. Gill PARS Environmental, Inc. 609-890-7277	*Full-Scale Nanoiron Injection For Treatment of Groundwater Contaminated With Chlorinated Hydrocarbons* http://www.parsenviro.com/reference/klockner-NGT-III-2005.pdf

* Note: Sites highlighted in gray and with an '*' indicate that the data have not been independently verified.

U.S. EPA OSWER
Selected Sites Using or Testing Nanoparticles for Remediation

Site Information							Media		Contaminants			Technology Information		Vendor Information	
Site Name	**Site location (city, state)**	**EPA Region**	**Site type**	**Cleanup program**	**Scale**	**Geology**	**Media treated**	**Volume of media treated**	**Contaminants treated**	**Initial contaminant concentrations**	**Final contaminant concentrations**	**Type of nanoparticle**	**Technology design**		**Cleanup/ remedial objectives and goals**
* Industrial Plant	Rochester, NY	2	Former Manufacturing	NYSDEC RCRA	Full	Glacial till overburden lying above fractured sedimentary bedrock.	Groundwater in overburden and weathered top of bedrock	Not available	TCE	TCE 1,900 ug/L	55-83% reductions in TCE from 1,900 ug/L to 330 ug/L (an 83% decline), and from 750 ug/L to 340 ug/L (a 55% decline).	Golder Associates nZVI: produced by Golder Associates Inc. under license from Lehigh University	nZVI slurry concentration of 10 to 20 g/L; Total nZVI injected 600 Kg; Pressurized injection using Geoprobe rig.	Pilot test designed and implemented by Golder Associates Inc. (Allen Kane, Florin Gheorghiu)	Not available
OU-2B	Alameda Point, CA	9	Navy Installation	Navy Installation Restoration Program	Pilot	Not available	Groundwater	Not available	TCE	Approximately 1,600 ug/L	Not available (test not yet conducted)	Surface-modified NZVI	Direct injection	Toda Americas	Not available
Ford Aerospace Site	Palo Alto CA	9	Aerospace Facility	Not available	Pilot	Groundwater encountered 8 to 10 feet bgs. Water table 6 feet bgs under confined conditions. Multiple water-bearing units. Sand and gravel zones separated by low-permeability clays.	Not available	Not available	PCE, TCE, Freon	PCE in source zone up to 26,000 ug/L PCE in dissolved plume along northern property line at 850ug/L from 10 - 60 ft bgs Offsite sources impact site, with TCE > 70,000 ug/L, Freon 113 > 1,000 ug/L	Not available	Starch-stabilized BNP (Fe/Pd)	Push-pull tests in field batch reactor	Geomatrix	Assess *in situ* transport and reactivity of nZVI particles
* Industrial Plant	Sheffield, AL	4	Private	N/A	Pilot	Unconsolidated sediments	Groundwater	Not available	PCBs, PCE, TCE, DCE, VC	10,000-24,000 ug/L	PCB reduction observed then rebounded. Chlorinated volatiles reduced greater than 90 percent.	Polysaccharide stabilized bimetallic nanoiron - Golder Associates, Auburn University on site production of stabilized nZVI	Precipitated, variable concentrations	Pilot Test designed and implemented by Golder Associates Inc. (Jeff Paul and Feng He) and Auburn University (Don Zhao)	None Specified
* Former Chemical Storage Facility	Winslow Township, NJ	2	Private	CERCLA	Pilot	Unconsolidated sediments	Groundwater	Not available	PCE, TCE, DCE	TCE 3,000 ug/L	One order of magnitude decrease in the injection well	Golder Associates nZVI: produced by Golder Associates Inc. under license from Lehigh University	nZVI slurry concentration of 5 to 10 g/L; Total nZVI injected 150 Kg; Gravity feed injection.	Pilot test designed and implemented by Golder Associates Inc. (Stephen Finn, Heather Lin, Florin Gheorghiu)	Source mass reduction
* Manufacturing Plant	Trenton, NJ	2	Manufacturer	Private	Pilot	Shallow aquifer, approximately 7 to 25 feet bgs	Soil and Groundwater	Not available	PCE, TCE, c-DCE, vinyl chloride, chloroform, carbon tetrachloride, 1,1-DCE	TCE pre-injection: 445 to 800µg/L Max TCE: 4600 µg/L	Contaminant concentrations reduced by 1.5% to 96.5%	BNP (Fe/Pd) Particles	MW (DGC-15) served as the point of injection. Approximately 1.7 kg of nanoscale particles were fed into the test area over a 2-day period. First day- 890 L of 1.5 g/L Second day- 450 L of 0.75 g/L	Not available	Evaluate amenability of synthesized nanoparticles, assess groundwater chemistry changes, and evaluate efficacy of nanoparticles for transformation of chlorinated hydrocarbons
* Alabama Site	Northern Alabama	4	Abandoned Metal Processing Plant	Not available	Pilot	Not available	Soil and Groundwater	Not available	PCE, TCE, and PCBs	TCE: MW-1 (1655 ppb) MW-2 (3710 ppb)	TCE: MW-1 (72 ppb) and MW-2 (less than 10 ppb)	Carboxymethyl cellulose (CMC) stabilized zero-valent iron	Test area was approximately 135 square feet. 150 gallons of 0.2 g/L Fe-Pd nanoparticle suspension was synthesized on site and gravity fed into the test area over a 4 hour period	Collaboration between Golder Associates. Fisher, Acros Organics, and Strem (supplier of nanoparticles)	Confirm effectiveness of the nanoparticles, mobility of the particles in soil, and ability to degrade contaminants

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Performance Information									Cost Information	Future Work/Current Plans	Contact Information	Information Sources
Site Name	**Site location (city, state)**	**Were cleanup goals and objectives met? (Yes/No)**	**Performance data available (Yes/No)**	**Maintenance (O&M) activities/ monitoring system**	**Start date/date installed**	**Anticipated end date of current phase**	**Length of operation**	**Comments**				
* Industrial Plant	Rochester, NY	Yes	No	Not available	2006	Not available	Not available	N/A	Not available	Post-remediation monitoring	Allen Kane, Golder Associates 610-941-8173 akane@golder.com	Email communication from Golder Associates
OU-2B	Alameda Point, CA	N/A	No - test not yet conducted	N/A	N/A	N/A	N/A	N/A	Not available	Not available	Mark Losi Tetra Tech ECI 949-756-7516 mark.losi@tteci.com	Mark Losi
Ford Aerospace Site	Palo Alto CA	N/A	No	Not available	2006	31-Jan-08	Not available	N/A	Assuming $50 per pound, 1 g Fe/L, cost for treating 1 cy = $21 (materials costs only)	Decided to utilize different technology to remediate site.	Matt Dodt, Ford Motor Co., 312-248-7554 Lester Feldman, GeoMatrix, 510-663-4240	Local Applications of Innovative Groundwater Cleanup Using Zero Valent Metals http://www.epa.gov/region09/science/ZVmetals-for-GW-Cleanup.pdf Interim *in situ* groundwater remediation, 21 August 06, appendices D and E
* Industrial Plant	Sheffield, AL	Not available	Yes	Chemicals taken to site, set up preparation at well head, injected in one point, monitored at 3 locations	Feb-07	Not available	Not available	N/A	Not available	Not available	Jeff Paul, Golder Associates Inc. 770-492-8150 jpaul@golder.com	Email communication from Golder Associates
* Former Chemical Storage Facility	Winslow Township, NJ	Not available	Yes	Not available	Apr-05	Completed	3 Months	ORP data: Initial values about -100 mV; after injection maintained at -300 mV for more than 3 months The nZVI had a limited radius of influence	Not available	Not available	Heather Lin, Golder Associates 856-793-2005 hlin@golder.com	Email communication from Golder Associates
* Manufacturing Plant	Trenton, NJ	Yes	Yes	Not available	Phase I - May-00 Phase II - Jun-00	Not available	Phase I - 45 days Phase II - 23 days	ORP data: Pre-Injection = 150 to 250 mV with a pH between 4.5 and 5.5 The nanoparticle plume traveled at an apparent velocity of 0.8 m/d, exceeding the natural seepage velocity of 0.3 m/d ORP and pH changes following injection will aid in growth of anaerobic microorganisms	Not available	Conduct laboratory and field tests for fate and transport; assess effectiveness of nanoparticles on other contaminants, and develop modeling tools to characterize subsurface transport of nanoparticles	H.S. Gill PARS Environmental, Inc. 609-890-7277	*Field Assessment of Nanoscale Bimetallic Particles for Groundwater Treatment* Environmental Science & Technology Vol. 35, No. 24, 2001
* Alabama Site	Northern Alabama	Yes	Yes	Not available	Not available	Not available	29 days of field injection and monitoring - 1 full year including preparation	ORP data: Reduced from -40 mV to -254 mV in MW-1	Not available	Not available	Don Zhao Auburn University 334-844-6277 dzhao@eng.auburn.edu	*Project Completion Report: Pilot-Testing an Innovative Remediation Technology For In-Situ Destruction of Chlorinated Organic Contaminants in Alabama Soils and Groundwater Using a New Class of Zero Valent Iron Nanoparticles.* Auburn University. June 2007.

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